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Final Research Report Agronomic and Economic Evaluation of Conventional vs. Conservation Wheat-Based Cropping Systems under Normal Irrigation and End-Of-Season Drought Stress

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Abstract

Over five crop years (2013–2018) in Karaj, split-plot trials compared six annual and biennial wheat-based rotations under two tillage systems (conventional vs. no-till) and two irrigation regimes (full vs. terminal drought). Key findings:

- **Yield trends:** Under conventional tillage, wheat yield did not rise over five years; under no-till, yields steadily increased—partly by buffering end-season drought and harnessing positive "rotation carry-over."
- **Rotation synergy:** Diverse two-year sequences, especially wheat→clover→canola→maize, delivered the highest grain and biomass yields, sustaining both production and soil health.
- **Soil improvement:** No-till increased surface organic carbon (0.45 → 0.81 %), improved aggregate stability, cation exchange capacity, porosity, and water-holding capacity, enabling 50 % water savings by doubling irrigation intervals.
- **Economic return:** Average four-year yield gain was +4 165 kg/ha. Net present value under no-till cover-crop rotations reached rials124 million/ha, with a 73.1 % ROI.

Conclusion: In irrigated, small-scale wheat systems of Alborz, a two-year rotation that integrates green manure (e.g. clover), reduced shallow vertical tillage, and temporary raised beds can neutralize late-season drought, boost yields, and deliver robust economic returns.

1. Introduction

Wheat is Iran's strategic staple but confronts erosion, declining soil carbon, nutrient stratification, and escalating weed resistance. Late-season irrigation cuts due to competing summer crops compound drought stress during flowering and grain fill. Conservation agriculture (CA)—minimum tillage, residue retention, and diverse rotations—offers a systems-based remedy for water conservation, soil fertility, and yield stability.

2. Objectives

1. Quantify how end-season drought and tillage system (conventional vs. no-till) affect wheat agronomic and physiological traits.
2. Assess rotation and residual carry-over effects on wheat yield, quality, and economic returns.
3. Identify the most profitable, drought-resilient cropping system for Alborz Province.

3. Materials & Methods

Design: Split-split-plot in randomized complete blocks, four replicates • Main plots: Conventional tillage vs. no-till • Subplots: Six rotations (two-year sequences of wheat, maize silage, canola, clover) • Sub-subplots: Irrigation regimes—full vs. terminal drought (final irrigation withheld at flowering)

Raised-bed planting (60 cm bed width), no residue burning, two passes of light disc harrow per year for seedbed prep in no-till, weekly summer irrigation for cover crops, and 20 % of fields allocated each year to a 45-day fallow + 65-day cover crop cycle.

Measurements: Grain and biomass yield, yield components, water use efficiency, soil physical/chemical/biological indicators, grain quality (protein, gluten, SDS sedimentation), and partial budgeting for economic analysis.

4. Key Results

4.1 Grain Yield Trends (kg/ha)

– Conventional: 6 829 → 5 470 (years 1→9) – No-till: 6 390 → 6 943

After year 5, no-till yields dipped under prolonged direct-seeded residue retention, but switching to two shallow vertical passes instead of moldboard plow and maintaining raised beds restored yields by year 9.

4.2 Water Efficiency

Irrigation per kg grain dropped from 0.77 → 0.61 m^3 in no-till cover-crop systems.

4.3 Soil Improvements (Years 1→4)

Organic C: 0.45 → 0.81 % Aggregate stability ↑, bulk density ↓ slightly, water-holding up by ~20 %.

4.4 Cover Crop Biomass (60–65 days growth)

Top producers: • Sudangrass sorghum: 12 000 kg DM/ha • Forage millet: 8 800 kg DM/ha • Berseem clover: 9 022 kg DM/ha

Millet and sudangrass thrived under intermittent irrigation, adding the most organic C and suppressing weeds allelopathically.

4.5 Economic Analysis

4-year yield gain: +4 165 kg/ha Total cost (wheat + cover crop): 145 million rials /ha NPV (4 years): 111 million rials /ha (max 124 million rials with millet) ROI: 64.6 % (up to 73.1 % in millet system)

5. Conclusions & Recommendations

1. **Adopt two-year rotations** with at least three to four unlike crops (e.g. wheat→clover→canola→maize) for both conventional and no-till systems.
2. **Avoid burning residues**; retain 30–85 % of residue on the surface and incorporate lightly with disc harrow.
3. **Limit continuous no-till** on irrigated wheat to < 5 years before a shallow vertical tillage pass to break compaction and renew bed geometry.
4. **Integrate summer cover crops**—preferably millet, sudangrass, or clover—for 60–65 days between wheat harvest and planting; no pesticides/fertilizer needed.
5. In terminal drought years, CA systems buffer soil moisture and mitigate yield loss—fungible for fall horticulture if desired.
6. Economic and environmental benefits—water savings, carbon sequestration, weed and pest reduction—emerge within 2–3 years, ensuring farmer adoption.